therefore forms a most necessary and valuable introduction to a complete survey of the heavens on the same method. The instrument used was the Voigtländer photographic doublet, of 8 inches aperture and 44 inches focal length, so that the scale of the photographs was that of the atlas of the *Durchmusterung*, 2 centimetres to a degree. The images of the stars obtained on the plates were of different kinds, the clock sometimes being employed to drive the telescope when the stellar images were points or disks, sometimes the clock was stopped when trails were obtained, sometimes the clock was used but trails produced through the polar axis of the telescope not being parallel to that of the earth; indeed the adjustment of the polar axis was made in this way. The standard for measuring the stellar points was a photograph of the Hyades, the plate being exposed six times with exposures of 3 seconds, and 3^2, 3^3, to 3^6 seconds respectively. For measuring trails a plate was exposed to the polar region, and the aperture of the telescope varied to correspond to successive differences of a magnitude. The result of the careful and independent measurements of the plates showed that the measures of a skilled observer of the same star disk or trail did not vary on the average by so much as a tenth of a magnitude; so that if the errors due to the photographs themselves can be eliminated the photographic method of determining stellar magnitudes is at least as efficient as the best photometric methods. The comparison of the diurnal with the clock trails showed that the correction for declination to be applied to the former was only half $2·5 \log \cos \delta$, the value it should have had if the chemical action due to a certain amount of energy was independent of the time during which it acted.

The first of the three catalogues given in this work is that of the stars within 1° of the pole. Rectangular co-ordinates are given with the stars, instead of R.A. and declination. Of the 1009 stars included, 947 are within one degree radius from the pole, and nearly all are above the fifteenth magnitude. The catalogue of the Pleiades includes all of Wolf's stars between 3m. preceding, and 2m. following Alcyone, and 30′ north and 15′ south of that star with a few apparently overlooked by Wolf. The equatorial catalogue contains the stars within 2° of the equator. Ten different fields were photographed on each plate, one being exposed on the meridian, eight others right and left at intervals of 40m. hour angle, and the tenth on the polar region. A comparison of the results obtained brings out some interesting points. Tempel, at Marseilles, observing the Pleiades with a 4-inch telescope, reached fainter stars than Wolf at Paris with 12 inches aperture. The behaviour of photographic lenses of different apertures shows that to double the aperture is to command two additional magnitudes; to treble it, two and a half. A 24-inch aperture should, therefore, grasp stars below the seventeenth magnitude. A comparison of the photographic magnitudes with the Cordoba Catalogue, and the *Durchmusterung* gives distinct maxima for the residuals in the Milky Way, showing that the Catalogue magnitudes are too faint near the Galactic stream where stars are numerous.

ASTRONOMICAL PHENOMENA FOR THE WEEK 1889 *MAY* 5-11.

(FOR the reckoning of time the civil day, commencing at Greenwich mean midnight, counting the hours on to 24, is here employed.)

At Greenwich on May 5

Sun rises, 4h. 26m.; **souths**, 11h. 56m. 32·0s.; daily decrease of southing, 5·1s.; **sets**, 19h 27m.: **right asc. on meridian**, 2h. 50·7m.; **decl.** 16° 23′ N. **Sidereal Time at Sunset**, 10h. 22m.

Moon (at First Quarter on May 8, 7h.) **rises**, 7h. 57m.; **souths**, 16h. 17m.; **sets**, 0h 35m.*: **right asc. on meridian**, 7h. 11·7m.; **decl.** 22° 41′ N.

Planet.	Rises. h. m.	Souths. h. m.	Sets. h. m.	Right asc. and declination on meridian. h. m.	° ′
Mercury..	4 44	12 43	20 42	3 37·3	20 51 N.
Venus ...	3 44	11 24	19 4	2 17·8	17 59 N.
Mars ...	4 52	12 44	20 36	3 38·2	19 47 N.
Jupiter ...	23 46*	3 42	7 38	18 35·2	22 57 S.
Saturn ...	10 32	18 11	1 50*	9 6·6	17 47 N.
Uranus ...	16 46	22 15	3 44*	13 10·7	6 48 S.
Neptune..	5 18	13 4	20 50	3 58·3	18 52 N.

* Indicates that the rising is that of the preceding evening and the setting at of the following morning.

May.	h.	
5	17	Mercury in conjunction with and 1° 9′ north of Mars.
7	22	Saturn in conjunction with and 1° 28′ south of the Moon.

Saturn, May 5.—Outer major axis of outer ring = 41″·0: outer minor axis of outer ring = 11″·6: southern surface visible.

Variable Stars.

Star.	R.A. h. m.	Decl. ° ′		h. m.	
U Cephei	0 52·5	81 17 N.	May 6,	1 52	*m*
			,, 11,	1 31	*m*
X Boötis	14 18·9	16 50 N.	,, 10,		*m*
δ Libræ	14 55·1	8 5 S.	,, 6,	23 51	*m*
W Herculis	16 31·3	37 34 N.	,, 6,		*m*
U Ophiuchi	17 10·9	1 20 N.	,, 6,	2 30	*m*
			,, 6,	22 38	*m*
U Aquilæ	19 23·4	7 16 S.	,, 11,	1 0	*M*
S Vulpeculæ	19 43·8	27 1 N.	,, 8,		*m*
η Aquilæ	19 46·8	0 43 N.	,, 9,	1 0	*M*
S Sagittæ	19 51·0	16 20 N.	,, 6,	22 0	*M*
S Aquilæ	20 6·5	15 18 N.	,, 10,		*m*
X Cygni	20 39·0	35 11 N.	,, 7,	2 0	*M*
T Vulpeculæ	20 46·8	27 50 N.	,, 11,	23 0	*m*
δ Cephei	22 25·1	57 51 N.	,, 8,	21 0	*m*

M signifies maximum; *m* minimum.

Meteor-Showers.

	R.A.	Decl.	
Near ε Crateris	170°	10° S.	Very slow.
,, η Ophiuchi	255	20 S.	Slow; long.
,, ζ Draconis	260	64 N.	Slow.

GEOGRAPHICAL NOTES.

THE discovery is announced of a new mouth of the Zambesi, forty-five miles south of the Quaqua, on which Quillimane is situated. The name of the river is Chindé. As we know already of a Chindé River which joins two of the principal mouths of the Zambesi, the probability is, not that a new mouth has been discovered, but that an already known mouth has been more completely explored. The Chindé, it seems, has a channel some 500 yards wide, with three fathoms of water at the lowest, and is therefore expected to afford a clear waterway to the main Zambesi.

FOR the last few years Baron Nordenskiöld has been engaged on a work of great importance in the history of geography, and especially of cartography. He has been collecting from the archives of various European countries specimens of the earliest printed (as distinguished from manuscript) maps, and some of his finds are really original discoveries. These he intends to reproduce in a great atlas with accompanying text, in which, among other things, he will describe and discuss the various editions of Ptolemy; of these he has formed a unique collection. The work will appear both in a Swedish and an English edition.

THE country of Oklahoma, about which we have heard so much during the past fortnight, is in the very heart of what is known as the Indian Territory, which lies between Kansas on the north and Texas on the south. Although on the Survey maps of the United States it seems to be well watered, the actual results would show that the water is not well distributed. It is traversed by the Canadian and Cimarron rivers, and between them are found on the map a perfect network of streams. The area of Oklahoma is a little over 3000 square miles, equal to about one-twentieth of the total area of the Indian Territory; the number of Indians in the latter is about 80,000.

IN an article in the May number of the *Fortnightly Review*, by Mr. F. C. Selous, the well-known South African hunter and explorer, we find a useful account of Mashonaland, around which at present there is so much interest. No man knows the country so well as Mr. Selous, who during the past ten years has traversed it in all directions. Mashonaland lies to the north-east of the Matabele country, and is described as a land of perennial streams, where thirst is an unknown quantity. The high plateau, which is of very great extent, forms the watershed between the Zambesi to the north and east, and the Limpopo and the Sabi

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to the south; it is from 4000 to 4600 feet above sea-level. Nearly the whole of it is magnificently watered by a network of running streams, the springs supplying which well out from the highest portions of the downs, so that an enormous area of land could be put under irrigation. The whole year round a cool wind blows almost continuously from the south-east, a wind which in the winter months becomes so cold that it may well have its origin among the icebergs of the Antarctic seas. The country, Mr. Selous assures us from his own experience, is admirably adapted for European occupation and labour. The soil is rich and fertile, and from the facilities for irrigation enormous quantities of wheat could be grown. Although the highest and healthiest parts of the country are very open, still one is never out of sight of patches of trees. Besides the high plateau of Mashonaland, the whole of which is over 4000 feet above sea-level, extending along the watershed for a distance of over 200 miles from the Matabele country to the source of the Hanyane and Mazoe Rivers, with a breadth of from sixty to one hundred miles, there is a vast extent of country lying to the south, east, and north-east of the plateau, well-watered and fertile, having an altitude of from 3000 to 4000 feet. These plateaus are of much ethnological interest, as giving shelter to the very few remnants of the peaceful Mashonas that have escaped extermination at the hands of the bloodthirsty intruders, the Matabele.

MR. SELOUS leaves England for the Cape to-morrow. It is possible that he may be compelled to lead a prospecting party up the Zambesi. Should this not be the case, he is likely to proceed northwards beyond the Zambesi to the Garenganze country, west of Lake Bangweolo, and thence make either for the source of the Lualaba, which he will endeavour to follow down until it broadens out into the Congo.

M. J. TAUPIN, Professor in the College of Interpreters at Saïgon, has completed an important exploration in the lower Laos country. Starting from Saïgon in October 1887, M. Taupin, after visiting the Siamese province of Siem-Reap, and photographing the numerous Khmer remains in that province, notably those of Angkor, crossed the forests of the lower Laos, to Ubon, where he resided several months. Among other things he has obtained a knowledge, at least summary, of the Laotian language and writing, the only graphic-alphabetic system, it is stated, on which we have no positive information. The language, M. Taupin states, is spoken by four million people. He has surveyed about 1000 kilometres of rivers and watercourses not found on any map, besides making many important corrections. He has made many notes on natural history, and experimented with the culture of European plants. The meteorology and anthropology of the country, moreover, received much attention at his hands.

AT the next meeting of the Geographical Society, on May 13, the evening will be mainly occupied with a discussion of Mr. Stanley's letters, in which several well-known African authorities are likely to take part.

CAPTAIN BINGER, a French explorer, has succeeded in filling up one of the blanks on the map of Africa. Starting from the banks of the Niger, he penetrated the country of Kong, amid many dangers and sufferings.

THE HENRY DRAPER MEMORIAL.[1]

THE researches which constitute the Henry Draper Memorial have consisted for the last three years in the photographic study of the spectra of the stars. While this subject will continue to be the principal one under investigation, Mrs. Draper has decided to extend the field of work undertaken, so as to include the study of the other physical properties of the stars by photography. As will be seen from the detailed statement below, the first research undertaken is now rapidly approaching completion, the plans for the study of the southern stars have been matured, and this study will soon be begun; the detailed study of the spectra of the brighter stars is making progress, and a large piece of photometric work will soon be undertaken with a new telescope. The progress made in each investigation will now be described, as in previous Reports.

1. *Catalogue of Spectra of Bright Stars.*—The Bache telescope, which has an 8-inch photographic doublet as an objective, is used for this work. The photographs cover the entire sky north of −25°, with exposures of about five or ten minutes. About 28,000 spectra of 10,800 stars have been examined, including nearly all stars visible in Cambridge of the seventh magnitude or brighter. The Catalogue is now nearly ready for the printer, the final copy having been prepared as far as 14h. in right ascension.

Nearly the entire time of three or four computers has been devoted during the past year to this work. The intensity of about 15,000 of the spectra has been measured, completing this part of the research. Much time has been spent in checking and verifying the results. All the positions have been checked and brought forward to 1900 two or more times independently. All discordant measures have been re-examined, and a search has been made for possible error when bright stars are omitted or very faint ones inserted. Seven thousand two hundred notes have been made on the various stars in the Catalogue. Each note has an appropriate number which permits it to be entered in its proper place. Most of these notes relate to additional lines contained in these spectra besides those by which the type is determined. The position and intensity of these lines is estimated. A portion of them have been reduced to wave-lengths. The printing of the Catalogue might have been already begun but for the difficulty of deciding how the different types of spectra should be distinguished. The classification used for visual observations fails to indicate many differences obvious in the photographs. On the other hand, the photographic portions of spectra of Types II. and III. are nearly identical. The photographs also show many stars whose spectra are intermediate between those of the typical stars which have determined the usual classification. A system has, however, been adopted which permits all differences detected in the photographs to be described in the printed volume.

Thirteen spectra were found on these plates which could not be identified with stars. Three of these proved to be due to Mars, one to Vesta, three to Jupiter, four to Saturn, and two to Uranus. Accordingly all the exterior planets bright enough to be detected in this way appear on these plates.

The measures of the intensity of the spectra form a very important portion of this work. Since the same part of the spectrum is measured in each case, the true relative energy is determined. That is, the same result is obtained as if the measures of rays of the same wave-length were made by any other method, as photometrically by the eye, by the thermopile, or by the bolometer. The colour of the star will be indicated by the extent of the spectrum, which is also noted. For the first time, therefore, we shall have a photometric Catalogue in which the error due to the colour of the star is eliminated. A preliminary determination of the accordance of the results derived from different photographs of the same star shows that the average value of the residuals will be about 0·16, which is the same as the corresponding quantity for the Harvard Photometry. The number of stars is more than twice that contained in the latter Catalogue.

2. *Catalogue of Spectra of Faint Stars.*—In November 1888, the photographs required to cover the sky north of the equator were nearly finished. It was expected that in two months the observations would be completed. The telescope, which was the same as that used in the previous research, was, however, wanted for photographing the Solar Eclipse of January 1, 1889. It was accordingly sent to Willows, California, where it was mounted, and the greater portion of the remaining photographs were taken there. It was then sent to Peru, as will be described below. The few remaining photographs, including the repetition of those found on further examination to be unsatisfactory, will be taken in Peru.

3. *Detailed Study of the Spectra of the Brighter Stars.*—The 11-inch refractor with one, two, or four large prisms over its objective has been employed in this work throughout nearly every clear night, until stopped by the morning twilight; 686 photographs have been taken, most of them with an exposure of two hours. With our present photographic plates about 570 stars north of −30° are bright enough to be photographed with one prism, 170 of them with two prisms, and 87 of them with four prisms. To obtain the best possible result some of the photographs must be repeated many times. The difficulty is increased by the invariably hazy appearance of the lines in some spectra, like that of α Aquilæ, which was at first attributed to poor definition of the photograph. It is expected that the work will be completed during the next year by original or repeated photographs of 228 stars with one prism, of 64 with two, and of 12 with four. In general, stars as bright as the

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[1] "Third Annual Report of the Photographic Study of Stellar Spectra conducted at the Harvard College Observatory," Edward C. Pickering, Director. (Cambridge: John Wilson and Son, University Press, 1889.)

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